SHORT-TERM MEMORY FOR COMPLEX MEANINGFUL VISUAL CONFIGURATIONS: A DEMONSTRATION OF CAPACITY[1]

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ABSTRACT

This experiment concerned an aspect of short-term memory somewhat neglected in the past, namely, the ability to remember, i.e., to recognize, complex meaningful visual configurations. S's task was to inspect an extended sequence of photographs of assorted content and to identify those which were occurring for the second time within the sequence. The probability of recognizing the recurrence of a photo as such was very high even with as many as 200 items intervening between its first and second occurrence.

MANY, IF NOT MOST, laboratory investigations of human memory have tended to call attention to some rather severe limitations on our ability to store and retrieve information. For example, it has been repeatedly demonstrated that the average human adult can recall in order, and without error, only about six to eight randomly ordered verbal items after seeing or hearing them once (Miller, 1956). It makes very little difference whether the items are familiar words, nonsense syllables, letters, or decimal or binary digits (Brener, 1940; Hayes, 1952). Performance is better, but not phenomenally so, with prose; the ability to repeat a 19-word sentence after a single hearing has been considered to be one indication of superior intelligence (Terman & Merrill, 1937). When given the task of keeping track of the current states of a set of randomly changing variables, one typically does even more poorly than might be expected on the basis of performance in span experiments (Reid, *et al.*, 1961; Yntema, 1963).

Even with recognition memory tasks performance in the laboratory has been something less than awe inspiring. For example, the probability that an individual will recognize the second occurrence of a 3-digit number in a sequence of such numbers has been reported as being about .75 when 6 or 7 numbers intervene between its first and second occurrence

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The author wishes to thank Miss Juliana Peterson for her assistance in the preparation of stimulus materials and the collection of data. The idea for the experiment grew out of a discussion with Dr. Charles R. Brown.

in the sequence, and dropping to about .57 with as many as 60 intervening numbers (Shepard & Teghtsoonian, 1961). With "meaningless" black and white visual configurations as stimuli, Mooney (1960) got recognition rates not greatly different than chance when 15 items intervened between the initial and subsequent occurrence of the item to be recognized.

It is not the purpose of this paper to question either the reliability or importance of such findings. The objective is simply to emphasize another, and to some extent antithetic, aspect of human memory: our somewhat more impressive ability to remember complex meaningful stimulus configurations, as, for example, pictures of people, places, and things. The experiment was intended primarily as a demonstration that with appropriate stimulus materials and task situation the amount of information that an individual can carry along in memory may be quite large indeed.

Method

A set of 600 black and white photographs, representing a broad spectrum of subject matter, was selected from photography periodicals. Each photo was mounted on a piece of 8½ × 11 white construction paper, covered with transparent cellulose acetate to minimize wear from extensive handling, and placed in one of several loose leaf binders in accordance with the following ordering scheme. The first 200 photos contained no duplicates. Half of the subsequent 400 photos were duplicates, that is, they were occurring for the second time within the series. We will refer to an item as *new* on its first occurrence and *old* on its second occurrence, and to the number of items intervening between the first and second occurrence of a given item as *lag*. The sequence of photos was ordered so that 40 different old items occurred at each of 5 lags: 40, 80, 120, 160, and 200. A rectangular distribution of lags was maintained throughout the sequence; that is, at any arbitrary point in the sequence, each lag had been sampled an equal (+ 1) number of times. The patterning of old and new items appeared random. An algorithm for constructing sequences of this type is described in detail elsewhere (Nickerson & Brown, 1963).

S was allowed to look at each photo for five sec., turning the notebook pages on cue from an audio signal paced by an electric timer. No responses were made to the first 200 photos. Immediately after looking at the 200th photo S was cued to begin responding and thereafter the task was to designate each photo as either new or old. Four hundred responses were collected from each of 56 Ss, most of whom were female college students.

Results

General Performance Level

The general performance level was high: 95 per cent of all responses were correct. The lowest scoring subject was correct on better than 80 per cent of the trials.[2]

[2]My thanks to one of this journal's consultants for bringing to my attention an experiment reported by R. N. Shepard to the Eastern Psychological Association in

Effects of Lag

Figure 1 shows the proportion of old stimuli at each lag which were correctly identified as old. A non-parametric test of trend (Hayes, 1957) showed the effect of lag to be significant ($p < .01$); however, from the figure it can be seen that the effect was small over the range of lags sampled. Even at the maximum lag used, that is, 200 items, 87 per cent of the old items were correctly identified as such.

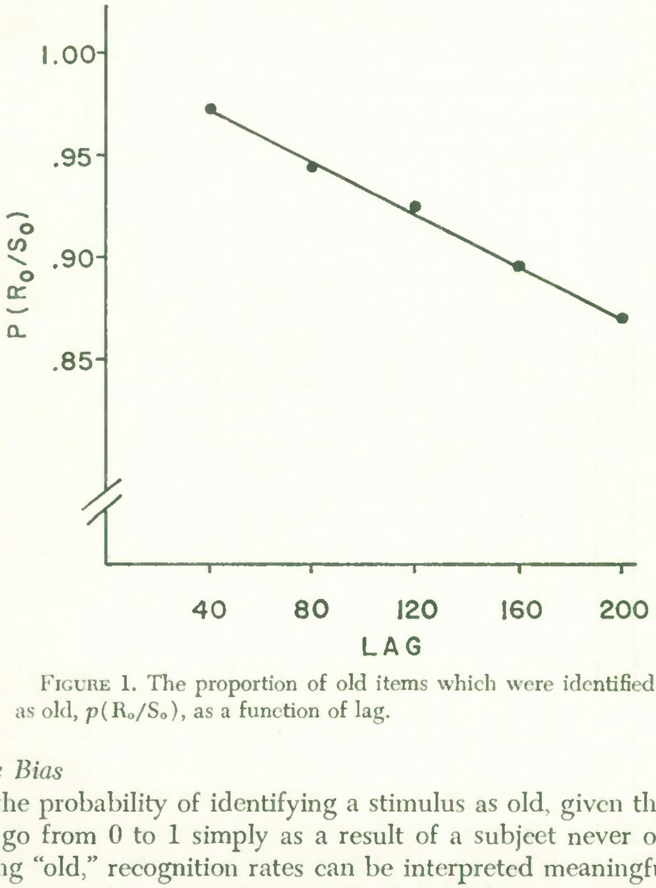

FIGURE 1. The proportion of old items which were identified as old, $p(R_o/S_o)$, as a function of lag.

Response Bias

Since the probability of identifying a stimulus as old, given that it was old, can go from 0 to 1 simply as a result of a subject never or always responding "old," recognition rates can be interpreted meaningfully only in conjunction with response frequencies. A small but consistent response bias was observed in this experiment. Although (excluding the first 200

April, 1959, and briefly described in C. N. COFER & B. S. MUSGRAVE, eds., *Verbal behavior and learning: problems and processes* (New York: McGraw-Hill, 1963, p. 29). The present experiment differed procedurally from Shepard's in several important respects; however, the results substantiate his finding of exceptionally high recognition memory performance with pictorial material.

items) old and new stimuli occurred with the same frequency, 89 per cent of the subjects made slightly more "new" responses than "old." The bias decreased during the course of the experiment, until during the last fourth of the trials the two responses occurred with almost exactly the same frequency.

Contingent Performance Measures

For the great majority of subjects (approximately 90 per cent) new stimuli were more frequently correctly identified than were old, but the response "old" was more likely to be correct than was the response "new." Letting, for example, $p(R_o/S_o)$ represent an estimate, based on obtained relative frequencies, of the probability of the response "old" given an old stimulus, and pooling the responses of all subjects, the following contingent probability estimates were obtained: $p(R_n/S_n) = .979$; $p(R_o/S_o) = .921$; $p(S_n/R_n) = .926$; $p(S_o/R_o) = .978$.

Discussion

The general performance level provides a somewhat different picture of short-term memory capacity than does the more conventional span experiment, and even represents a marked contrast to the results of other experiments designed to investigate recognition memory as a function of lag. Furthermore, it should be remembered that in no sense did this experiment measure the upper limits of performance. A maximum lag of 200 items was chosen simply because the experimenter expected a much steeper forgetting curve than was actually obtained. Extrapolating the results leaves little doubt that lags much larger than those used would yield recognition rates well above chance.

The stimuli in the present study were both complex and meaningful and it seems likely that to a large extent the results are attributable to this fact. However, the exact roles of complexity and meaningfulness are not at all obvious. A random re-arrangement of the dots comprising a photographic image could, in a sense, be at least as complex as the picture itself, but a set of such random dot arrangements would not be expected to yield very high recognition rates. On the other hand, meaningfulness of material alone, without the complexity and diversity of subject matter, would hardly be sufficient to guarantee results such as those obtained.

The degree of interitem similarity would be expected to be an important determinant of performance in a recognition memory task, and although we have made no attempt at quantitative comparisons, it seems reasonable to conjecture that the stimuli of this experiment were probably

less similar to each other than are a set of 3-digit numbers, and perhaps even than the visual configurations used by Mooney (1960).

Although exactly what gets stored when one looks at a picture remains to be determined, it is clear that one need not remember every detail in order to recognize it on a subsequent occurrence. It may be recognized on the basis of its over-all theme, or by one or two unusual or striking features. How much detail need be remembered depends, in part, on the degree of similarity between the item and those from which it must be distinguished.

It is also clear that the stored representation of a visual image need not necessarily bear a close resemblance to the image itself to provide an adequate basis for recognition. A stimulus configuration may undergo a variety of cognitive transformations before being committed to memory. Features may be abstracted and sharpened, or ignored and filtered out. A composition may be simplified, categorized, and labelled, or it may be intentionally elaborated, embellished, or projected into a "colourful" or more "memorable" context (Bartlett, 1932). Associations may be formed between the content of the immediate visual experience and that of relatively long-term memory. For example, a "nonsense" figure may remind one of a camptosaurus or a map of New Guinea, and it may be easier to remember what one is reminded of than the figure *per se*. Providing the figure prompts the same association on different occurrences, remembering the association—or associate—may be sufficient under many conditions to assure recognition of the figure.

Irrespective, however, of the transformations an input may undergo in the process of being committed to memory, and of the strategies that may be brought to bear to enhance recognition, whatever is stored must be sufficient to provide a basis (1) for differentiating that item from the others with which it might be confused and (2) for determining the correspondence between the stored representation of an item and its recurrence as a visual experience.

Shepard and Teghtsoonian estimated the lower bound on the amount of information carried along by subjects in their experiment with 3-digit numbers to be about 32 bits. It would be interesting to assess a subject's performance in the present experiment in informational terms; however, we are not aware of any very satisfactory technique for doing so. The information value of an event represents the degree to which one's ignorance or uncertainty is reduced by the occurrence of that event. In order to estimate it one must know, or assume, what the individual considers to be the probability of the occurrence of the event before it occurs. In the case of a well-defined and limited set of alternative events, e.g., 3-digit decimal numbers, the determination may be straightforward; with

haphazardly selected pictures it is not. In the latter case, the set of possible alternatives must be very large and *a priori* probability associated with the occurrence of each, very small indeed. It seems likely that any realistic estimate of the amount of information that is actually being carried along in store in the performance of a task such as that of this experiment must be considerably higher than many studies of short-term memory capacity might lead us to believe possible.

Résumé

Etude d'un aspect jusqu'ici assez négligé de la mémoire à court terme: la capacité de se rappeler, c'est-à-dire de reconnaître des configurations visuelles complexes (intelligibles.) La tâche du sujet consiste à examiner une séquence de photographies à contenu varié et à identifier celles qui reviennent une seconde fois dans la séquence. La probabilité de reconnaître le retour d'une même photo s'avère très élevée même quand il intervient jusqu'à 200 item entre la première et la seconde présentation de la photo.

REFERENCES

BARTLETT, F. C. *Remembering: a study in experimental and social psychology.* Cambridge: Cambridge University Press, 1932.

BRENER, R. An experimental investigation of memory span. *J. exp. Psychol.*, 1940, 26, 467–82.

HAYES, J. R. M. A non-parametric test of trend. *Psychol. Newsletter*, 1957, 9, 29–34.

——— Memory span for several vocabularies as a function of vocabulary size. *Quart. progr. Rep.*, M.I.T. Acoustics Laboratory, Jan.–March, 1952, 5–9.

MILLER, G. A. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychol. Rev.* 1956, 63, 81–97.

MOONEY, C. M. Recognition of ambiguous and unambiguous visual configurations with short and longer exposures. *Brit. J. Psychol.*, 1960, 51, 119–25.

NICKERSON, R. S., & BROWN, C. R. A stimulus ordering technique for controlled lag recognition memory experiments. *Psychol. Rep.*, 1963, 13, 319–22.

REID, L. S., LLOYD, K. E., BRACKETT, H. R., & HAWKINS, W. F. Short term retention as a function of average storage load and average load reduction. *J. exp. Psychol.*, 1961, 62, 518–22.

SHEPARD, R. N., & TEGHTSOONIAN, M. Retention of information under conditions approaching a steady state. *J. exp. Psychol.*, 1961, 62, 302–9.

TERMAN, L. M., & MERRILL, M. A. *Measuring intelligence.* Boston: Houghton Mifflin, 1937.

YNTEMA, D. B. Keeping track of several things at once. *Human Factors*, 1963, 5, 7–8.

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